The global burden of diabetic foot disease

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Diabetic foot problems are common throughout the world, resulting in major economic consequences for the patients, their families, and society. Foot ulcers are more likely to be of neuropathic origin, and therefore eminently preventable, in developing countries, which will experience the greatest rise in the prevalence of type 2 diabetes in the next 20 years. People at greatest risk of ulceration can easily be identified by careful clinical examination of the feet: education and frequent follow-up is indicated for these patients. When assessing the economic effects of diabetic foot disease, it is important to remember that rates of recurrence of foot ulcers are very high, being greater than 50% after 3 years. Costing should therefore include not only the immediate ulcer episode, but also social services, home care, and subsequent ulcer episodes. A broader view of total resource use should include some estimate of quality of life and the final outcome. An integrated care approach with regular screening and education of patients at risk requires low expenditure and has the potential to reduce the cost of health care.

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As the world is facing an epidemic of type 2 diabetes and an increasing incidence of type 1 diabetes[1,2] the International Diabetes Federation has chosen to focus on the global burden of diabetic foot disease in 2005. The lifetime risk of a person with diabetes developing a foot ulcer could be as high as 25%,[3] and it is believed that every 30 seconds a lower limb is lost somewhere in the world as a consequence of diabetes.[4] The International Diabetes Foundation has therefore declared that now is the time to increase awareness of foot problems in diabetes[5] in view of the vast personal, social, medical, and economic costs of what should be one of the most preventable long-term complications of diabetes.[6]

The burden of diabetic foot disease is set to increase in the future since the contributory factors to foot disease, such as peripheral neuropathy and vascular disease, are present in more than 10% of people at the time of diagnosis of type 2 diabetes,[7] and the first year after diagnosis of diabetes is a period of danger for foot ulcers and amputations.[8] Moreover, the greatest rise in the prevalence of type 2 diabetes is likely to be in developing countries in Africa, Asia, and South America,[1] countries in which foot ulcers are more likely to be of neuropathic origin[9] and therefore highly preventable.[10] The challenge facing the global diabetes community is how best to implement screening, educational, and treatment programmes in every region of the world. In this Review we describe the epidemiology and economic consequences of diabetic foot disease across the world and speculate how we might best implement simple screening and preventive educational programmes.

Epidemiology of diabetic foot disease

Global collaborative studies

Given the evidence that the provision of a foot-care service can be associated with a reduction in amputations in diabetic patients,[11] a collaborative group was formed 10 years ago with the aim of comparing the incidence of amputations between communities across the world.[12] In their first report, this group described pronounced differences in amputation rates with the highest in native Americans and the lowest in Madrid, Spain (43·9 *vs* 2·8 per 100 000 per year); diabetes was associated with 25–90% of all amputations.[13]

Other collaborative groups have reported differences in diabetic foot ulcers between developed and developing countries[9] and within different European countries.[14] However, direct comparisons are difficult because of differences in populations studied and time periods over which data were obtained (table).

Europe

Most European countries have participated in the implementation of the international guidelines on diabetic foot care,[4] and many have established multidisciplinary foot clinics. However, much disparity remains: few eastern European countries have foot clinics or podiatry services. There have been several collaborative studies between European countries: one from Antwerp, Athens, Manchester, and Rome reported no major differences between patients attending hospital diabetic

	Year	n	Prevalence		Incidence	
			Ulcers	Amputations	Ulcers	Amputations
Population (community) based studies						
UK[15]	2002	9710	1·7	1·3	2·2	..
Greece[16]	2002	821	4·8	..	..	..
Netherlands[17]	2002	665	..	..	2·1	0·6
Slovakia[18]	1997	1205	2·5	..	0·6	0·6
USA[19]	1999	8965	..	..	1·9	0·3
Clinic-based studies						
Algeria[20]	1998	865	11·9	6·7	..	..
India[21]	1998	11300	3·6	..	..	..

Table: **Epidemiology of foot ulceration and amputations by country**

Search strategy and selection criteria

We based this review on our knowledge of the topic, extensive consultations with members of the International Working Group on the Diabetic Foot, and a comprehensive review of the relevant published work. We cross-checked information with searches on PubMed for articles recently published in the past 10 years using the index terms "diabetes", "neuropathy", "peripheral vascular disease", "foot ulcer", "amputation", "epidemiology", and "health economics".

clinics in terms of risk factors for foot lesions, including the prevalence of neuropathy and peripheral vascular disease.[14] These facts suggest that similar strategies for foot ulcer prevention might be equally effective across European countries.

A large population-based study from three districts in the UK confirmed that 1·4% of type 2 diabetic patients had active foot ulcers and 5% had ever had ulcers.[22] A larger community-based UK study reported a 2% annual incidence of foot ulcers,[15] similar to a comparable primary-care population in the Netherlands[17] (table). Perhaps a more important message from the community study was that simple clinical tests predict those at risk of ulceration,[15] which has implications for screening strategies in developing countries. A composite clinical score with dichotomous variables, the modified neuropathy disability score, was the best predictor of risk: this score requires only a tuning fork, a pin, and a tendon hammer, and no specialist equipment. Interesting data exist on foot ulcer risk for patients from ethnic minorities within the UK. Asians and African-Caribbeans seem to have a much reduced risk of foot ulcers.[23]

Interest in diabetic foot problems is increasing in France,[24] with one Parisian clinic reporting a 33% reduction in hospital inpatient stay after the establishment of a multidisciplinary foot-care team.[25] Success in reducing amputation rates in diabetic patients has varied across Europe. Although an unchanged incidence was reported from Germany,[26] more optimistic reports have come from the Netherlands and Italy.[27,28] The reduction in amputations could in part be a consequence of implementation of the International Consensus on the diabetic foot in Tuscany[28] and the increase in podiatry services provided in the Netherlands.[27]

Problems in diabetic foot care still exist in former Soviet countries, although progress is being made and a large meeting held in Moscow in Spring, 2005, was very oversubscribed. Multidisciplinary foot clinics now exist in large cities in a number of countries including Russia, Ukraine, Byelorussia, and Georgia. Of the former Soviet countries, however, the Baltic states probably have the best foot-care systems. More than seven foot clinics are now operational in Lithuania, and an institution of a multidisciplinary foot-care team and provision, when needed, of appropriate footwear resulted in a 48% reduction of recurrent ulcers over 2 years.[29]

Asia

In view of the vast population of this continent, data about diabetic foot problems are sparse. The International Working Group on the diabetic foot has reported that five specialist foot-care clinics exist in China (population 1287 million).[4] There are no podiatry services in China and amputations remain common: interest in the diabetic foot is now increasing and some centres have established multidisciplinary teams.[30] India has more people with diabetes than any other country,[1] and foot problems and amputations remain very common.[4] As in other developing countries, foot ulceration presents late and is most frequently associated with neuropathy and gross infection.[9,21,31] Barefoot gait is common and social and cultural beliefs can lead patients to seek help from traditional healers or village elders.

Other Asian countries with historical links to Europe have benefited from educational and training visits by overseas experts. Thus, for example, teams of podiatrists, surgeons, and diabetologists from the Netherlands have visited Indonesia to assist with diabetic foot care in Jakarta.

Africa

Sub-Saharan Africa contains 33 of the 50 poorest countries in the world, and this region will experience the greatest rise in the prevalence of diabetes in the next 20 years.[1] Diabetic foot complications constitute an increasing public health problem and are a leading cause of admission, amputation, and mortality in diabetic patients,[32–34] and yet since neuropathy is the major cause, they should be, in many cases, preventable.[9] A review of the epidemiology of diabetic foot problems in Africa[32] highlighted not only the frequency of neuropathy, but also the increasing frequency of peripheral vascular disease, presumably a result of increasing urbanisation. Unhygienic conditions, poverty, frequent co-existing HIV infection, barefoot gait, low income, and cultural practices often interact to compound the situation. Early diagnosis of foot lesions, education, and appropriate treatment of sepsis are essential to make a difference to these depressing statistics.[35] For some unfortunate patients, the tropical diabetic hand syndrome can co-exist with foot ulceration.[36]

Australasia

Although covering a vast area, this continent has low population density: diabetes, however, is common in the native and island people. Amputation rates in some island populations, such as Fiji and Nauru, were once extremely common but have been reduced following the institution of a national foot-care health education and prevention programme.[37] A similar education and training programme has been established in Australia, with telemedicine to aid rural population outposts.[38,39] A population-based study from Australia suggested that risk factors for foot ulceration might be lower than in other Western countries,[40] but a subsequent report showed that foot screening is poor, with less than half of the diabetic population reporting a regular foot examination.[41] As in Australia, the health-care system in New Zealand is well developed, but although podiatrists are available, they are below the recommended numbers.[42] In a study published in 1998, the number of admissions for diabetic foot disease actually increased over a 13-year period until 1993.[42]

North America

In the USA, diabetic foot complications are a major cause of hospital admission: in 1997, nearly 70% of all amputations were for people with diabetes.[43] Foot ulcers and amputations are more common in ethnic minority groups, especially hispanic and black people, who are less likely to have health insurance.[44,45] In the Caribbean, diabetes prevalence is approaching 20% in many islands, and amputations in diabetic patients are among the highest in the world.[46,47] Indeed, in one hospital in Barbados, patients with diabetic foot lesions occupied 75% of all surgical beds.[47]

South and Central America

The prevalence of diabetes is high in this region, ranging from 5% to 20%.[1,48] In northern Brazil, as in tropical areas of Asia and Africa, patients might have leprosy and diabetic neuropathy, both of which can contribute to foot complications. Diabetic foot care in Brazil is well organised, an example of excellent cooperation between health-care professionals and the ministry of health. With assistance from UK and US centres, the "Save the diabetic foot Brazil project" was initiated in 1992 in Brasilia, when the first multidisciplinary foot clinic was opened. 13 years later, over 60 clinics are operational across the whole country,[49] and there is increasing evidence that they are having an effect on amputation rates. Further north, a diabetic foot interest group has been formed in Colombia, and in Costa Rica, multidisciplinary hospital-based wound clinics are available to treat diabetic foot ulcers.[50]

Health economics

In addition to causing pain and morbidity, foot lesions in diabetic patients have substantial economic consequences. The cost of diabetic foot lesions is affected by interventions to prevent foot ulcers, management strategies to heal ulcers, which shorten wound healing time and prevent amputation, and by management and care necessary for disability after amputations.[51]

Diabetic foot ulceration and amputations were estimated to cost US healthcare payers $10·9 billion in 2001.[52,53] Corresponding UK estimates based on the same methodology were that 5% of total national health service expenditure in 2001 (£3 billion) was attributable to diabetes. The total annual cost of diabetes-related foot complications was estimated to be £252 million.[54] In these studies, resource use was estimated from hospital episode data and clinical opinion. Patients with neuropathic or neuroischaemic ulcers, but not those requiring amputation, were included in these cost estimates, which only included the estimated direct medical costs of treating foot complications associated with diabetes.

These estimates have been based on the following assumptions: an annual incidence of foot ulcers of 2–6%, a prevalence of 3–8%, recurrence rates of 50–70% within 5 years, average healing rates of 11–14 weeks, and 1-year amputation rates of 15%. It is also estimated that amputations are preceded by foot ulcers in 75–85% of cases, usually in association with infection and gangrene. However, in addition to the direct costs of foot complications, there are also indirect costs relating to loss of productivity, individual patients' and family costs and loss of quality of life. Therefore, based on present studies in North America and Europe, up to 20% (7–20%) of total expenditure on diabetes might be attributable to the diabetic foot.[18,52–61] This figure includes total expenditure, including postoperative rehabilitation and home care.

Cost of management and treatment

In a review of compiled cost data from studies published between 1994 and 2000[51] adjusted for inflation and currency conversion, the cost of diabetic foot ulcers not requiring amputation ranged from US$993 to US$17 519 (1998 equivalent). In one study, however, the cost of an ulcer episode for the first 2 years after diagnosis was $30 724.[19] The lowest costs were evident in studies based upon insurance charges and young patients, whereas the highest costs were in patients with deep foot infections. However, comparisons of results from various health-economic studies are complicated by differences in study design (prospective *vs* retrospective, primary care *vs* secondary care data), selection of patients, type of foot lesions, healthcare systems and settings, treatment practices, time for analyses, the perspective of studies, reimbursement system, and countries included. Moreover, especially in some of the earlier studies, details of costing and other methodological details are sometimes limited or missing.

When discussing the treatment costs of diabetic foot ulcers it is important to clarify proportional costs for different uses of resources in relation to total costs. In a Swedish prospective study following up diabetic patients with foot ulcers until healing without amputation,[61] the most expensive healed were inpatient care (37% of total costs) and topical treatment of wounds (45% of total costs). For those patients who eventually required amputation, the same two items were again the most expensive inpatient care (65%) and topical treatment of wounds (13%).[62] Perhaps surprisingly, the costs for antimicrobial drugs, outpatient visits, and orthopaedic appliances were low in relation to the total costs in both categories of patients. In the same study, the total cost for healing a foot ulcer was strongly related to the severity of lesion.

Cost of lower extremity amputations

In a review assessing cost data for diabetic foot lesions,[61] the estimated cost of amputation ranged between US$16 488 and $66 215 (1998 currency). As expected, costs were lower in those studies based on inpatient hospital costs only, with the highest resource use in patients with major lower extremity amputations that included total direct costs until healing. In these studies,

amputation has been regarded costly as a result of its consequences (such as nursing and institutional care) rather than the cost of the surgical procedure itself. The economic costs for a minor lower extremity amputation (foot level) were $43 800 and for major lower extremity amputation (above ankle) $66 215, of which 77% of the cost was after the actual amputation.[61] A substantial part of the inpatient care for patients undergoing amputations is not undertaken in surgical departments, but in other units such as internal medicine, infectious disease, rehabilitation medicine, or nursing homes,[61,62] This is why it is necessary to follow up patients with regard to resource use until a specific endpoint (eg, complete healing or completion of successful rehabilitation). Consequently, prevention of foot ulcers and therefore many amputations must be the most important actions to reduce such high expenditure.

Long-term perspective

Few studies have estimated costs of the long-term follow up of patients with foot ulcers. Such analyses should take into account the risk of recurrent ulceration and amputation as well as the use of resources resulting from complications and disability caused by the previous lesions. In a prospective study following up patients after foot ulcer healing, reulceration rates at 1, 3, and 5 years were 34%, 61%, and 70%, respectively.[63] In those patients with recurrent ulcers, the highest costs were for inpatient care, social services, and home care. The major costs for outpatient care were related to topical management of recurrent ulcers where staff costs and transportation dominated. Actual expenditure for outpatient visits, antibacterials, and off-loading of materials were small. For those who underwent a major amputation, annual extra costs for social services and home care were high. Total costs corrected to 1998 currency were US$16 437 for non-ischaemic lesions, $27 203 for ischaemic lesions, $43 892 for minor amputation, and $64 265 for major amputation.[63]

Costing parameters

Cost calculations must be able to differentiate between those costs attributable to foot complications and those arising as a consequence of non-foot related disease, for example the treatment of inter-current diseases or other diabetic complications. The problem is that many published economic studies of diabetic foot disease have been based upon information from databases or claims data.[64] Similarly, costs for diabetes have been underestimated when based on patients' statistics or secondary databases.[65–67] The major problem with economic analyses of diabetic foot lesions based on these kinds of data is that a breakdown of resource use is often not available.[64]

In a study comparing resource use associated with diabetic foot infection in three European foot centres in different countries, substantial differences were identified in inpatient stay, use of antibiotics, and vascular surgery.[68] The authors concluded that these differences could largely be explained by variations in access to inpatient and outpatient facilities, selection bias of patients, patients' characteristics, reimbursement systems, and health-care systems. In a comparison of diabetes-related foot lesions in patients in the Netherlands and California,[69] the duration of hospital stay was substantially longer in the Netherlands whereas the incidence of lower extremity major amputation was higher in the USA. The authors suggested that these differences might be explained by differences in access to health care, health-care financing, and reimbursement systems. In the Netherlands, as in many European countries, most people are provided with affordable government health care whereas in the USA, costs are often paid by the patient or by the patient's insurance company. If the cost of an amputation procedure is reimbursed but the cost of outpatient care is not, this fact could affect the rate of lower extremity amputation.

The cost-effectiveness of prevention

In a cost-utility analysis based on the Markov model, it was suggested that if intensive prevention could reduce the incidence of foot ulcers and amputations by 25%, the simulated preventive strategy would be cost effective and save money in all patients with diabetes mellitus except in those without specific risk factors:[70] preventive education should therefore focus on those with risk factors. The study was based on model simulation of people with diabetes and different risk factors, optimum prevention, including education of patients and appropriate foot care according to international recommendations (including multidisciplinary management); this approach was compared with actual prevention and standard care in the Swedish population. The results suggested that providing care for all people with any risk of diabetic foot ulcers (eg, sensory neuropathy, neuropathy plus ischaemia, previous foot ulcers, foot deformity, and so on) was suggested to be highly cost effective or even save costs in these subgroups. However, for people with no further risk factor except diabetes, additional preventive measures to avoid foot ulcers or amputation would not be cost effective.

These findings have subsequently been confirmed in two other European studies,[71,72] which claimed that management of the diabetic foot according to present guidelines would result in improved survival and reduced number of diabetic foot complications. Furthermore, it would be cost effective or even save money compared with standard care if the incidence of ulceration and amputation was reduced by 25–40%.[70–72] Another factor that is difficult to measure but could be important for cost effectiveness or preventive foot care is patients' adherence to education and management. The incentive for adherence might be low when the cost of prevention has to be paid by the person with diabetes and the cost for treatment is covered by the health-care system.[51,55]

Conclusion

Diabetic foot problems are common throughout the world, and the economic consequences are major, both to society and to the patients and their families. When assessing use of resources, it is important not to focus on individual items such as dressings or procedures. Rather, a broader view of total resource use that includes some estimate of quality of life and the final outcome should be taken. The key question remains as to how we can reduce the morbidity and even mortality resulting from diabetic foot disease. The answer might not be too difficult. When Paul Brand was asked to make a recommendation on reducing amputations in diabetes to a US Department of Health conference, most listeners were probably expecting an answer promoting vascular surgery or modern medications. They were surprised to hear that his key recommendation was a national campaign to encourage health-care professionals to remove patients' shoes and socks and examine the feet.[6] Unfortunately, however, this simple advice is ignored in many countries. Identification of the at-risk foot does not require any expensive equipment: a tuning fork, pin, tendon hammer, and a 10-g monofilament should suffice.[4,6,10,15] Education and more frequent follow-up should be focused on those with at-risk feet.[70]

When planning an educational programme, it should be remembered that many patients do not understand what neuropathy or a foot ulcer are.[73] Education should be tailored to the patient's understanding and social background. Organisation of the foot-care service is important:[49] an integrated care approach can improve patients' outcomes, disability, morbidity, and mortality.[74] Even in large countries such as China and India, where diabetes is common and most people live in rural areas, a screening programme such as that suggested by Paul Brand could be highly effective with little cost to the health-care system. Finally, many societies have issued guidelines on diabetic foot care,[4,10,75] most of which include essential components of recommended education for patients.

Contributors

A J M Boulton and L Vileikyte researched the global epidemiology, J Apelqvist and G Ragnarson-Tennvall the health-care costs. The final manuscript was prepared by A J M Boulton and J Apelqvist and approved by all authors.

Conflict of interest statement

We declare that we have no conflict of interest.

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